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Synthesis, Characterization, and Application of Tunable Resistance Coatings Prepared by Atomic Layer Deposition

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ABSTRACT

We have developed a nanocomposite coating comprised of conducting, metallic nanoparticles embedded in an amorphous dielectric matrix. These films are comprised of M:Al_2O_3 where M= W or Mo, and are prepared by atomic layer deposition (ALD) using alternating exposures to trimethyl aluminum (TMA) and H_2O for the Al_2O_3 ALD and alternating MF_6/Si_2H_6 exposures for the metal ALD. By varying the ratio of ALD cycles for the metal and the Al_2O_3 components in the film, we can tune precisely the resistance of these coatings over a very broad range from 10^{12}-10^5 Ohm-cm. These films exhibit Ohmic behavior and resist breakdown even at high electric fields of 10^7 V/m. Moreover, the self-limiting nature of ALD allows us to grow these films inside of porous substrates and on complex, 3D surfaces. As a result of these qualities, these nanocomposite films have proved to be exceptional as charge drain coatings in electro-optical MEMS devices, and as resistive coatings in solid-state electron multipliers (microchannel plates, MCPs).

In this study, we employed *in situ* quartz crystal microbalance (QCM) and Fourier transform infrared (FTIR) absorption spectroscopy to understand the ALD growth mechanism for the nanocomposite films. In the case of the Mo:Al_2O_3 films, QCM showed that the Mo ALD inhibits the Al_2O_3 ALD and vice versa. Despite this inhibition, the relationship between Mo content and Mo cycle percentage was close to expectations. Surprisingly, FTIR revealed that the reducing agent for the Mo is not the Si_2H_6, but rather the TMA exposure from the subsequent Al_2O_3 ALD cycle. Depth profiling x-ray photoelectron spectroscopy showed that the M:Al_2O_3 films are uniform in composition and contained Al, O, and metallic Mo or W as expected, but also include significant F and C. Cross sectional transmission electron microscopy revealed the film structure to be metallic nanoparticles (~1 nm) embedded in an amorphous matrix.

We have utilized these nanocomposite coatings to functionalize capillary glass array plates to fabricate large-area MCPs suitable for application in large-area photodetectors. In addition, we have applied these films to serve as charge drain coatings in MEMS devices for a prototype electron beam lithography tool, and obtained high resolution electron beam patterns without charging artifacts.